# Fine Woody Debris of *Mangifera indica, Alstonia macrophylla,* and *Calophyllum inophyllum* Affected Soil Hydrophobicity

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**Abstract**

***Mangifera indica* (MI), *Alstonia macrophylla* (AM), and *Calophyllum inophyllum* (CI) are medicinal plants with specific chemical compositions in leaves, roots, stem, and fruits/nuts. Among these, MI is known to have astringent, acrid, and refrigerant roots and bark, whereas AM and CI are been reported for the presence of Alkaloids and Flavonoids, respectively, in stem-bark. These chemicals have specific characteristics that might interfere with and thereby change some soil properties. The objective of this study was to examine the effects of woody debris on soil hydrophobicity and wetting behavior using fine woody dusts. Arable top soil (0 –10 cm) (Udults) used for the experiment was air dried and sieved through 2 mm sieve. Air dried and ground woody dusts were sieved through 1 mm sieve prior to mixing with sieved soil to obtain 5 and 50% contents. Samples were exposed to four temperature levels (27, 60, 100, and 200°C) for 6 h. Hydrophobicity of soils was determined, in three replicates, with sessile drop contact angle of a water drop on a monolayer of samples fixed to a glass slide using a double-sided adhesive tape. Microphotographs of the drops were taken within 1 s by digital microscopic camera. Samples mixed with 5% woody dusts did not show a measurable contact angle within 1 s due to lateral wetting of the monolayers. Contact angle in samples with 50% woody dusts was highest with CI, followed by AM and MI. Presence of flavonoids might be the reason for CI to show a high hydrophobicity. The hydrophobicity of all the samples increased with time after heating which was measured up to 7 d. Contact angles of samples with 50% woody dusts increased by 12–16° with increasing temperature from 27 to 100°C. This can be attributed to changes in organic compounds in the woody dusts with the increasing temperature. Upon exposure to 200°C, hydrophobicity disappeared in all the samples showing that the organic materials responsible for causing the hydrophobicity lost either by evaporation or removal as $CO_2$ and $H_2O$.**

***Keywords:*** *Contact angle, Heat exposure, Hydrophobicity, Woody dusts*

## INTRODUCTION

*Mangifera indica* (MI), *Alstonia macrophylla* (AM), and *Calophyllum inophyllum* (CI) are medicinal plants with specific chemical compositions in leaves, roots, stem, and fruits/nuts. Among these, MI is known to have astringent, acrid, and refrigerant roots and bark, whereas AM and CI are been reported for the presence of Alkaloids and Flavonoids, respectively, in the stem-bark.

Xanthones and flavones are secondary plant metabolites and exhibit broad spectra of biological activity. The stem bark of CI is reported to contain prenylated dipyranoxanthone inophinone, together with two other xanthones, inophyllin A and caloxanthone. These chemicals have specific characteristics that might interfere with and thereby change some soil properties. Xanthones and flavones are reported for their hydrophobic properties in chemical analysis (Pogodaeva *et al.*, 2011) can be assumed to accumulate in soils with the decomposition of litter materials.

Although soils are generally considered to be readily wet table, some are actually water repellent at the surface and in the rhizosphere. Soil water repellency is a widespread phenomenon occurring in different soils and environments across the world at a variety of scales. It is a dynamic phenomenon, which is caused by low-energy surfaces where the attraction between solid and liquid phases is weak. If molecules of liquid surface have stronger attraction to molecules of solid surface than to each other, surface wetting occurs. Alternatively, if liquid molecules are more strongly attracted to each other than to molecules of solid surface, liquid beads-up and repellency appears. Soil water repellency adversely affects infiltration, evaporation, and erosion (Wallis and Horne, 1992). It has wide ranging implications for soil fertility, hydrology, and stability.

The appearance and degree of water repellency are thought to be closely related with organic matter. The degree of hydrophobicity is identified as to be positively correlated with soil organic matter (Mataix-Solera & Doerr, 2004). Water repellency is thought to be caused by hydrophobic organic compounds, although the presence of such compounds does not always lead to water repellency. Most of previous investigations around the world have attributed water repellency primarily to coating on soil particles. Coating of hydrophilic mineral particles with hydrophobic organic substances makes soils water repellent. Fatty acids, alcohols, esters, and alkanes in soil organic matter are associated with soil water repellency (Franco *et al.*, 1995). However, mineral particles need not be individually coated with hydrophobic substances. Merely intermixing mineral soil particles with organic matter may induce severe water repellency.

Xanthones and flavones present in the stem bark of CI and alkaloids in AM might induce hydrophobic properties in soil. The objective of this study was to examine the effects of woody debris on soil hydrophobicity and wetting behavior using fine woody dusts.

## MATERIALS AND METHODS

***Study site:*** Arable top soil (0–10 cm) obtained from Mirissa, Sri Lanka (Udults) was used for the experiment. The land use is agricultural, mainly with vegetable crops.

***Sample preparation:*** Soil was air dried and sieved through 2 mm sieve before mixing with organic materials. Woody debris of *Mangifera indica* (MI), *Alstonia macrophylla* (AM), and *Calophyllum inophyllum* (CI) was ground using a mechanical grinder and passed through 1 mm sieve. Sieved woody debris was mixed with sieved soil in proportions of 5 and 50%. Soil without woody debris was used as the control.

***Heat treatment :*** Samples were exposed to four temperature levels of 27°C, 60°C, 100°C, 200°C, with three replicates per treatment were implemented, for 6 h period, using laboratory oven and muffle furnace. Thereafter, the samples were left under the laboratory conditions (27±3°C, 75±5% relative humidity) for 24 h prior to the wet tability assessment.

***Sessile drop method;*** The sessile drop contact angle was measured on a monolayer of model soils fixed to a glass slide using a double-sided adhesive tape. The prepared samples were sprinkled on the adhesive tape with 1.5×1.5 cm dimensions fixed on a glass slide and the soil sample was pressed on to the tape with 100g weight for 10 s. The slide was tapped gently to remove the surplus soil. The prepared samples were kept in a room at 27± 3°C having 75±5% relative humidity. Glass slide with a sample was placed on the stage of a digital microscopic camera and a drop of distilled water (10±0.1 μL) was placed on the sample surface. A microphotograph of the horizontal view of the water drop was digitally taken within 1 s. The drop shape was monitored and recorded with the contact time. The contact angle of each sample was measured using the micro photographs considering the average of the both three phase contact points (Figure 1) of the drop (Leelamanie *et al.*, 2008). Samples mixed with 5% woody dusts and the control (only soil) did not show a measurable contact angle within 1 s due to lateral wetting of the monolayers.

Figure 2 shows the contact angle as a function of time in soils amended with 50% woody debris. Under 60°C, the hydrophobicity of all the samples increased with time after heating which was measured up to 7 d. Contact angle in samples with 50% woody dusts was highest with CI, followed by AM and MI as shown in Figure 1 (a). Presence of flavonoids might be the reason for CI to show a high hydrophobicity. Alkaloids are also found to be hydrophobic in nature, and thus have low solubility (Long *et al.*, 2012).

## RESULTS AND DISCUSSION

Although the hydrophobic properties of flavonoids and alkaloids are not been compared, our results showed high contact angle for CI with flavonoids compared with AM with alkaloids under 60°C. However, CI and AM did not show any significant difference under 100°C as shown in Figure 1.

On the other hand, samples with MI, which is known to have astringent, acrid, and refrigerant compounds, showed the lowest contact angles among the tested samples. However, it is interesting to note that all these samples, although they demonstrated significant differences, showed contact angles larger than 90° under both 60 and 100°C. However, for 100°C, the significance in these differences disappeared with increasing time from 1 to 7 d. Figure 3 presents the contact angle of samples with 50% woody debris and its behavior upon exposure to heat, in comparison with the control. Contact angles of samples with 50% woody dusts increased by 12–16° with increasing temperature from 27 to 100°C.

This can be attributed to changes in organic compounds in the woody dusts with the increasing temperature. Many evidences are available in the literature to conclude that drying soils at temperatures considerably above the room temperature would increase the hydrophobicity of soils (Crockford *et al.*, 1991; De Jonge *et al.*, 1999; Doerr, 1998; Doerr *et al.*, 2005). Dekker *et al.* (1998) reported that Dutch soils dried at 65°C showed greater potential water repellency compared with those dried at 25°C.

The exact cause of these heat-induced increases in hydrophobicity of natural soils is not entirely understood. However, it may be linked to improved alignment of hydrophobic molecules (Valat *et al.*, 1991), a more even distribution of repellent substances over soil grains (Savage *et al.*, 1972), migration of repellent materials from interstitial organic matter onto soil grains (Franco *et al.*, 1995), or transformation of organic compounds into more hydrophobic forms (Czachor and Lichner, 2013).

Upon exposure to 200°C, hydrophobicity disappeared in all the samples showing that the organic materials responsible for causing the hydrophobicity lost either by evaporation or removal as $CO_2$ and $H_2O$.

## CONCLUSIONS

Soil hydrophobicity significantly increased by adding 50% woody debris of CI, AM, and MI. Highest hydrophobicity was observed in samples amended with CI containing flavonoids, compared with those with AM containing alkaloids under 60°C. Samples with MI, which is known to have astringent, acrid, and refrigerant compounds, showed the lowest contact angles among the tested samples.

However, for 100°C, the significance in these differences disappeared with increasing time from 1 to 7 d. Exposure to heat induced changes in surface hydrophobicity of soil samples amended with woody debris.

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***Figures***

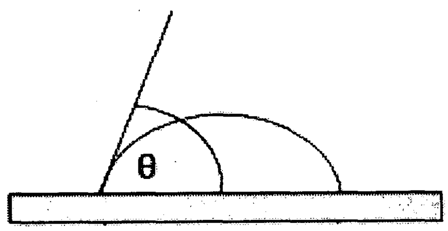


**Figure 1:** Contact angle (*θ*) on a solid surface

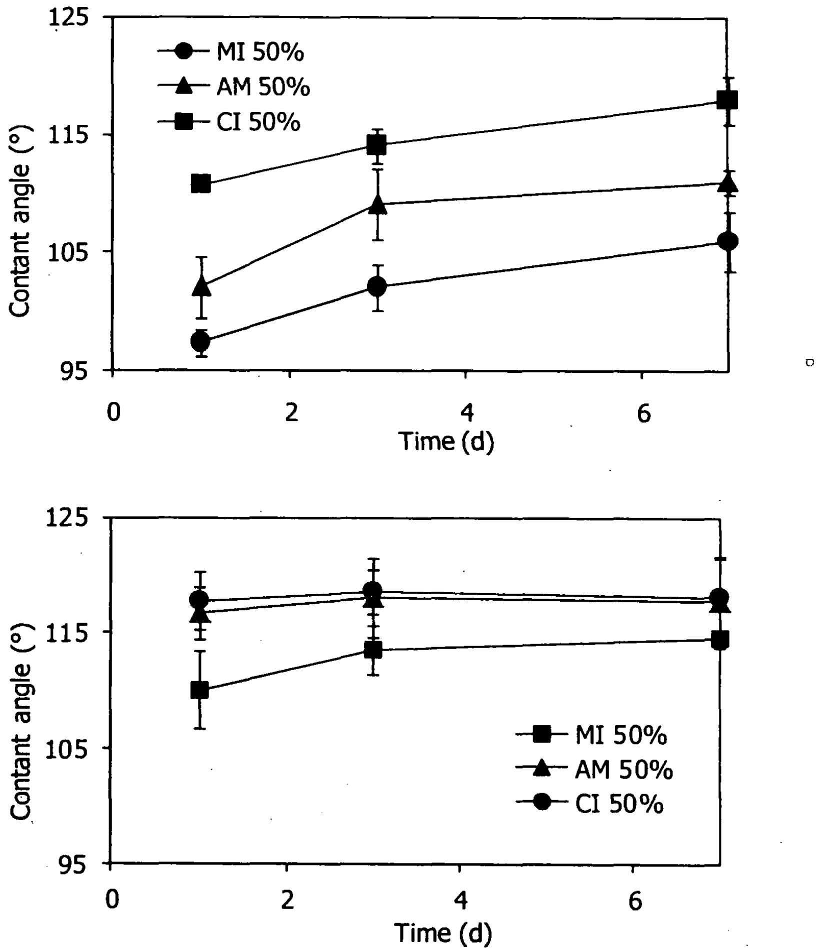


**Figure 2:** Contact angle as a function of time in soils amended with 50% woody debris under (a) 60°C and (b) 100°C. Error bars indicate ± standards deviation. MI: *Mangifera indica*; AM: *Alstonia macrophylla*; CI: *Calophyllum inophyllum.*

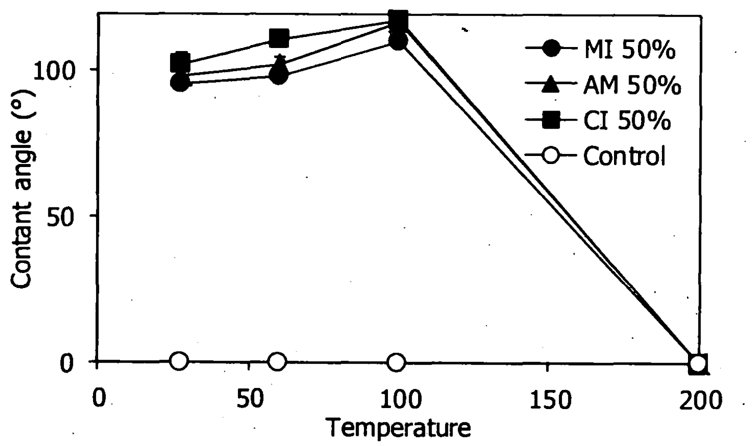


**Figure 3:** Contact angle of samples with 50% woody debris and its behavior upon exposure to heat. Error bars indicate ± standards deviation. MI: *Mangifera indica*; AM: *Alstonia macrophylla*; CI: *Calophyllum inophyllum*.